	Type	L #	Hits	Search Text	DBs	Time Stamp
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3	BRS	L3	163491	polyester	USPAT	2003/08/13 09:29
4	BRS	L4	106064	polyurethane	USPAT	2003/08/13 09:29
5	BRS	L5	277	thermal adj reflect$5	USPAT	2003/08/13 09:30
6	BRS	L6	110	2 and 3	USPAT	2003/08/13 09:30
7	BRS	L7	50	2 and 4	USPAT	2003/08/13 09:30
8	BRS	L8	1826	thermal same reflectivity	USPAT	2003/08/13 09:30
9	BRS	L9	136	thermal near reflectivity	USPAT	2003/08/13 09:30
10	BRS	L10	136	2 and 9	USPAT	2003/08/13 09:31
11	BRS	L11	23	3 and 9	USPAT	2003/08/13 09:31
12	BRS	L12	14	4 and 9	USPAT	2003/08/13 09:32

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nylon plastic

Properties
Very good physical properties
Moisture has significant effect on properties
Very good heat resistance
Excellent chemical resistance
Excellent wear resistance
Moderate to high price
Fair to easy processing

Applications
Electrical connectors
Gear, slide, cams and bearings
Cable ties and film packaging
Fluid resevoirs
Fishing line, brush bristles
Automotive oil pans
Fabric, carpeting, sportswear
Sports & recreational equipment

The family of nylons consists of several different types. Nylon 6/6, nylon 6, nylon 6/10, nylon 6/12, nylon 11, nylon 12, and nylon 6-6/6 copolymer are the most common. Of these, nylon 6/6 and nylon 6 dominate the market. The numbers refer to how many methyl units (-CH2-) occur on each side of the nitrogen atoms (amide groups). The difference in number of methyl units influences the property profiles of the various nylons. Moisture absorbance is decreased due to reduced polarity with further separation and less regular location of the very polar amide roups. Resistance to thermal deformation is lowered due to more flexiblity and mobility in these methyl unit sections of the main chain. As these units increase in length, making the molecules appear more like polyethylene, the properties of the nylon shift slightly toward those of polyethylene. Not considering the effects of moisture, Nylon 6/12 has lower modulus, higher elongation, lower strength, lower thermal distortion temperature, lower hardness and lower melting point than nylon 6/6. One relationship which does not conform is price. Nylon 6/12 is more expensive than nylon 6/6. The property which gives nylon 6/12 its utility is moisture absorption which is approximately half of that of nylon 6/6. This means the properties are much more consistent and experience less fluctuation due to ambient humidity levels in the end application.

Moisture absorption by nylon has been a source of great study for many years. Although all polymers absorb some amount of moisture, on none does it have such a significant effect as on nylons. Table 6.1 illustrates the moisture absorption levels of various types of nylons.

Table 6.1 Absorption of Moisture by Nylons by Weight % at 50% R.H. and Saturation @ 23øC

Type of Nylon	Equilibrium @ 50% R.H.	Equilibrium @ Saturation
6	2.7	9.5
6/6	2.5	8.0
6/10	1.5	3.5
6/12	1.3	3.0
11	0.8	1.9
12	0.7	1.4

Water molecules produce polar bonds with the amide groups in the nylon molecules. Although small, water molecules take up space and displace the nylon molecules. This results in the nylon molecular matrix swelling. Dimensional changes of 0.7% can result in nylon parts from the "as-molded" state to equilibrium at 50% R.H. environments. This change occurs in approximately 150 days for a 0.0 60 inch (1.5 mm) thick part. Molecular mobility is increased through the absorption of water. The increase in spacing between nylon molecules lowers the secondary forces allowing easier translational motion. This is the major reasons for the change in physical properties discussed above. There is less resistence to applied stress from the decrease in intermolecular friction. The change in molecular mobility is significant enough that molded nylon parts can relieve molded in stresses as they absorb moisture.

The absorption of moisture by nylon is a completely reversible physical reaction. Drying in an oven will drive off all but a small percentage of the water molecules which can only be removed through dissolution of the nylon molecular matrix. The rate of absorption/desorption varies with type of nylon as well as temperature and relative humidity. Addition of fillers reduces the effect of moisture both due to volume reduction of the ammount of nylon polymer in the mixture, and by sharing the attraction of the molecules somewhat reducing polarity and the available space for moisture molecules. Reinforcements reduce the effects more than fillers due to nylons strong affinity for reinforcement. In addition to the mechanisms which take place with fillers, the adhesion of the nylon molecular matrix to dimensionally stable reinforcements is stronger than than polar bonding of the water molecules and it dominates.

Another area where moisture has significant effects on nylons is in processing. Heated to molding temperatures while wet (ie., >0.2 % water) will result is hydrolytic degradation and a significant loss of physical properties. (Hydrolytic degradation is a chemical reaction which occurs at high temperature with some polymers in the presence of water. It causes primary bonds in the molecular chains to be severed thus reducing molecular weight.) Over drying (ie., <0.08% water) will remove the plasticizing effect of the water molecules and make the resin very viscous and hard to flow. The plasticizing effect in processing has to do with mobility and relative spacing of the nylon molecules, the same influence as on physical properties. This low level of moisture does not cause significant degradation during processing. The absorption of moisture by nylon must be considered in mold making. The shrinkage factor used in designing the mold must take the the potential for change in post molded dimensional into account. Although moisture causes problems in working with nylons, it does contribute to: better dyeability, toughness, softness and greater flexibility in nylon parts.

Another dominant feature of nylons is crystallinity. As with most crystalline polymers, the molecular chains are uncluttered by large substituent groups. They are flexible and regular in group spacing and crystallize readily. As with acetals, this crystallinity is responsible for properties of wear resistance, chemical resistance, thermal resistance, and unfortunately, higher mold shrinkage. The overall excellent property profile of nylons results in their probably having the most diverse range of applications of all thermoplastic polymers.

TIPS FOR MACHINING NYLON

STORAGE

Nylon has a high coefficient of thermal expansion (about three times that of aluminum)

and low heat conductivity. Make sure that it has been exposed to normal room temperature for several hours before it is machined into finished parts.

SAWING

Nylon can be easily sawed on standard metal working equipment. Wood working equipment may be suitable but the high cutting speeds may cause excessive heat build-up. A blade that has been used for cutting metal is usually not sharp enough for nylon. Use a new coarse tooth blade with good set. Coolant may be used to control heat buildup and to prevent melting the nylon.

HOLDING

Keep in mind that nylon is not as strong as metal and can be deformed by improper chucking methods. On small accurately sized rod, use standard spring collets. On larger parts, use a 6-jaw universal chuck instead of a conventional 3-jaw chuck to distribute the holding force more uniformly. For thin walled tubular shapes, machine soft jaws so that the part is almost entirely confined.

TURNING

Satisfactory finishes can be easily obtained on nylon over a wide range of surface speeds. Use tools that are honed sharp and have high rake and clearance angles, to minimize cutting force and reduce heat build-up. Chips will be continuous and stringy. They should be directed away from the cut and prevented from winding around the workpiece. Coolants are generally not necessary for lathe work unless there is excessive heat build-up.

MILLING

Milling cutters should be honed sharp and should have high positive cutting angles. Care should be used in clamping the part to prevent distortion. Double-faced pressure sensitive tape can be used to hold down flat parts. Cutting speeds and speeds will be determined by the finish required and will be limited by heat build-up.

DRILLING

Use conventional twist drill or flat type drills. Polished flutes will aid in the removal of chips. Do not use metal cutting reamers with nylon. They do not cut freely enough. Drill small holes to size in one operation. Rough drill large holes and finish by single point boring.

THREADING

Use only sharp taps and dies on nylon parts. Don't use tools that have been used to cut metal. H5 or even larger oversized taps may be required because a threaded hole in nylon closes in when the tap is removed. Threads to close tolerances can be easily single point chased.

GRINDING

The large amounts of heat generated by grinding, together with the low heat conductance of nylon, usually dictate that liberal amounts of coolant he used in most grinding operations. Thru-feed centerless grinding of long, flexible parts of nylon can be easily accomplished, and tolerances as close as .0005" are possible. Cylindrical grinding on nylon is usually not required because it is easy to get good finishes and close tolerances on a lathe. Suface grinding of nylon is usually not necessary. If a flat suriace with close tolerances and good finish are required, the best approach is fly cutting in a milling

machine.

STAMPING
Thin pieces may be stamped with standard equipment. Thick sections will require high shear angles if good edges are needed. Steel rule dies may be used for some parts.

MEASURING
Use ordinary measuring equipment. However, use a light touch because the material is not as hard as metal. A micrometer anvil can deform a nylon surface as much as several thousandths. Homemade, soft plug and ring gauges are useful on thin walled parts. If extremely close tolerances are involved, make sure any temperature changes that the part will see are taken into account.

PROPERTIES	A.S.T.M Test Method	NYLON	NYLON	NYLON	NYLON
		TYPE 6	TYPE 66	TYPE 612	CAST TYPE 6
Specific Gravity	D792	1.12 - 1.14	1.14 - 1.1	1.06	1.15
Water Absorption Method A	D570	2.9	1.24	0.25	-=-
Tensile strength at yield, 1000 psi	D638	9.4	12	8.8	11 - 14
Elongation at yield, %	D638	25	>150	7	10
Elastic Modulus in Tension, 10~5 psi	D638	-=-	4.4	-=-	3.5 - 4.5
Flexural Strength at yield, 1000 psi	D790	NO YIELD	16	NO YIELD	16 - 17.5
Elastic modulus in flexure, 10~5 psi	D790	1.50	4.1	2.95	-=-
Rockwell Hardness (Method A)	D785	R104	88	R114	R112
Izod impact strength, ft-lb/in. notch 1/8 in. speciman	D256	2.2	1.2	1.5	-=-
Deform. under load(2000 psi; 122f), %	D621	-=-	0.8	1.6	0.5 - 1.0
Deflection temperature, F at 66 psi fiber stress	D648	340	450	356	400
Max recommended service Temp., F continuous use	-=-	175	270	290	200 - 225

Coeff. of Linear Thermal Expansion, F	D696	4 x 10~5	4.5 x 10~5	5 x 10~5	5.0 x 10~5
Underwriters' Lab Rating (Subj. 94)	-=-	HB	V - 2	V - 2	-=-
Dielectric strength, v/mil, short time	D149	-=-	555	650	500
Dielectric constant at 60 Hertz	D150	7.2	4.0	4.0	3.7
Dielectric constant at 1 MegaHertz	D150	3.7	3.5	3.5	3.7
Dissipation factor, at 60 Hertz	D150	-=-	0.02	.02	-=-
Dissipation factor, at 1 MegaHertz	D150	0.12	0.03	0.2	-=-
Volume resistivity, ohm-cm	D257	10~12	10~15	10~15	-=-
Arc resistance (SS Electrode), sec.	D495	-=-	123	-=-	-=-

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HOME

MICROTHERM® THERMAL INSULATION

Thermal Conductivity

Definition

The effectiveness of a material as a thermal insulator can be expressed in terms of its thermal conductivity. The energy transfer rate through a body is proportional to the temperature gradient across the body and its cross sectional area. In the limit of infintesimal thickness and temperature difference, the fundamental law of heat conduction is:

$$Q=\lambda A dT/dx$$

where

- Q is the heat flow
- A is the cross-sectional area
- dT/dx is the temperature/thickness gradient
- λ is defined as the thermal conductivity value.

A substance with a large thermal conductivity value is a good conductor of heat; one with a small thermal conductivity value is a poor heat conductor i.e. a good insulator. Hence, knowledge of the thermal conductivity value (units W/m·K) allows quantitive comparisons to be made between the thermal insulation efficiencies of different materials. The most effective insulation will have very low thermal conductivity values. Our graphs show that MICROTHERM® has very low thermal conductivity values for a wide range of temperatures - in contrast with all the other material classes presented.

MICROTHERM®
THERMAL INSULATION

MICROTHERM® Thermal Conductivity Tables

The two tables below show thermal conductivity values for MICROTHERM® and other t insulation materials at different temperatures.

The first table shows metric units and the second imperial units.

Thermal Conductivity (W/m·K)

Mean Temperature (°C)	0°C	100°C	200°C	300°C	400°(
MICROTHERM® 240kg/m³	0.020	**0.022**	**0.024**	**0.026**	**0.029**
Calcium Silicate 240kg/m³	0.049	0.058	0.070	0.082	0.095
Ceramic Fibre Blanket 128kg/m³	0.031	0.041	0.056	0.075	0.099
Mineral Fibre Slabs 100kg/m³	0.031	0.046	0.066	0.091	0.122
Polyurethane Rigid Foam 32kg/m³	0.020	0.030			

Thermal Conductivity (Btu in /ft2h°F)

Mean Temperature (°F)	0°F	100°F	200°F	300°F	400°F	500°F	600°F	700°F
MICROTHERM® 15lb/ft³	**0.140**	**0.141**	**0.148**	**0.154**	**0.161**	**0.171**	**0.182**	**0.196**
Calcium Silicate 15lb/ft³	0.340	0.368	0.398	0.430	0.461	0.520	0.571	0.630
Ceramic Fibre Blanket 8lb/ft³	0.220	0.241	0.286	0.335	0.391	0.461	0.541	0.635
Mineral Fibre Slabs 6lb/ft³	0.220	0.254	0.312	0.380	0.460	0.550	0.663	0.780
Polyurethane Rigid Foam 2lb/ft³	0.139	0.150						